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SMART TECHNOLOGY-BASED PARKING

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Abstract

Downtown parking problems are majorly caused by combination of recent increase in number of motor vehicles with limited amounts of physical parking spaces. Parking problems promote unsatisfied motor vehicle drivers communities and downtown residents. Despite multiple mobile applications designed for locating parking spaces, it is still an open problem, and the available solutions cannot solve it to a satisfactory level. Our goal is to survey the demands in finding parking space (availability) and design a mobile application for finding parking spaces. In order to achieve our goal, we developed and conducted a public survey in collaboration with Worcester Polytechnic Institute. Based on the results of approximate 120 electronic survey responses, we developed an innovative parking system that features a mobile application, and future proposals to support and relieve parking conflicts in downtown regions.

Acknowledgements

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Executive Summary

Downtown parking problems in Boston area started after mid-1960s, when the number of automobiles increased drastically. Coupled with rapid urbanization and complicating downtown road maps, automobile drivers from the suburb and rural area and the residents in downtown area suffered from the extreme traffic and parking problems. Due to the relatively small size of Boston compared to other cities, with only wide 4-lane driveways, the city cannot sustain the rise in the number of automobile drivers because it lacks adequate affordable parking spaces and driveways, especially for the commuters who live in rural or suburb area. Consequently, there are poor roads and parking conditions in many of the downtown Boston areas. These parking spaces are poorly managed with limited number of spaces, creating a massive devastation during rush hours and weekends for the travelers, commuters and residents in Boston.

There are significant number of companies and offices located and available in the downtown areas. Many companies are mostly located in the heart of downtown in order to physically serve influx of customers face to face. Since the job market is heavily skewed in the downtown area, the employees have to commute to the downtown area. Consequently, the companies in downtown area are force to reserve spaces for office spaces and parking spaces, thus creating a busy and crowded downtown. Not only the employees have to drive to the busy sector in downtown, but also the customers have to travel to the downtown to purchase various kinds of services and products. These are factors that contribute to the significant parking problems manifested in the downtown area of Boston. Therefore, the mayor of Boston and the city council are currently attempting to resolve the myriad of problems. The city council recently installed couple of smart parking sensors on public parking streets and released a mobile application called Parker in attempt to aid motor vehicle drivers who desire to find parking spots (Streetline, 2014).

Because the mobile application is relatively new to the community, more research is required to understand the demands from the mobile application users.

The goal of this project was to create a smart parking system for motor vehicle drivers around downtown Boston area while simultaneously collecting information from the current downtown parking situation. In order to meet this goal, we achieve the following milestones. We surveyed the public to understand the current demands of mobile application features and designed both the user interface of the mobile application with those chosen features, and entire concept of the smart parking system in downtown area.

We achieved our objectives and milestone by examining government document and regulations, by using online surveying tools, and exploring various mobile applications that are on the market. By utilizing Worcester Polytechnic Institute Qualtrics, surveying the university population served as a helpful tool to further analyze the parking problems encountered by daily commuter. We have set multiple choice questions as well as open response questions so that the surveyors can easily communicate back to us with their inputs. We have created this survey to be anonymous because we did not need to identify personal information to conduct interviews. By utilizing the survey approach, our team was able to identify various findings such as residential location and work location of the general population. Once a general pattern or consensus is discovered, we record them and contribute those ideas towards the mobile application design.

By designing the entire smart parking system as well as the mobile application user interfaces and initial core features, we were able to create a conceptualization of the entire system. Although the mobile application does not currently have a running prototype, this survey result

could ultimately help the current Parker application, and help other people or organizations that currently attempt to solve the downtown parking problems.

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1. Introduction

Limited Parking spaces and general parking problems are persistent problems in many downtown areas. Majority of the jobs and offices are located in the heart of downtown areas, which draws travelers and people from other rural, and suburb areas (Doyle, 2012). Despite of large job and office numbers, downtown cities do not always have enough parking spaces for the large number of population (Woolsey, 2008). Limited parking spaces leads to increase in private parking rates. As a consequence, a large number of people are forced to wander in order to find a parking space or pay significant amount to park in downtown area. In downtown areas such as Boston, more and more people are experiencing parking difficulties.

Downtown areas experience serious lack of parking spaces because of both residents of downtown areas and drivers from outer cities desire to park in the downtown area. Downtown areas are not only designated for working people, but also home for a lot of people. In order to reserve some parking spaces for downtown residents, residential parking spaces were created. Only those who live in downtown areas can get residential parking permit, and those who do not have permit are not allowed to park in residential only spaces. Life in downtown area is not easy because residential lots do not adequately supply the current population. Both residents and travelers contribute towards current parking problems in downtown areas (Walsh, 2015).

There are not effective and fast ways to go into the downtown areas from rural or suburb areas. If there were other options than driving to downtown areas, many people would utilize them over driving to downtown because those options can save those people from the parking headaches. The public transportation system around Boston area, including commuter

rails, are seriously limited and undeveloped. Not many busses and trains operate beyond rush hours and transit times are usually longer than 15 minutes. Although improvements in public transportation can be seen recently, many rural areas beyond I-95 areas still have almost no access to public transportation system (Massachusetts Bay Transportation Authority, 2014).

Information about parking spaces are not readily available for those who are in need of it. Although private parking space information is somewhat available on multiple websites, public parking space information is hardly searchable. In order to find a public parking space, users would have to either explore around for a 2-hour or more free parking sign or zoom on maximum level in Google map satellite view in order to find the parking meters (Conti, 2014). Since the information for public parking spaces is not available and not broadcasted to those who actually need them, the searchers slowly wander around in narrow streets in downtown area and slow down the faster traffic.

While researching and surveying on the current demands of mobile application for searching parking space, the concept of the entire smart parking system was developed. The smart phone mobile application is a broadcast medium, we had to conceptualize how to capture various data and save it on a central database before broadcasting the data to multiple people and general public (Annear, 2013).

The goal of this project is to conceptualize a smart parking system, design a user interface for mobile application, and understand general user demand in mobile application features that would guide future smart parking mobile application. The project could provide statistical data of the current parking problems and will suggest and recommend potential solution to alleviate the parking problems in downtown areas. In order to achieve this goal, key objectives were identified: (1) Conceptualize the hardware and data component of the

smart parking system. (2) Survey the general public in order to understand their current situation and environment as well as demands in smart phone mobile application. (3) Design the user interface and core features reflecting the user feedbacks for initial mobile application release on the app store. In order to meet these requirements, we finalized the initial research, utilized the tools readily available for us, designed the survey questions aimed for general public, surveyed various groups of individuals in the university, analyzed and collected data from the survey results, and designed the smart parking system as well as user interface for mobile application. Based on the research findings, the general population desired a mobile application that could assist them in downtown areas, thus improving their lives in the future.

2. Background

2.1 Overview of Parking Problems

Finding a parking space in Boston as a motor vehicle driver is extremely difficult. There are approximately 645,966 people living in Boston. 23% of the commuters use some sort of public transportation system like MBTA, but the other 77% commute to their work by their cars (Woolsey, 2008).

Figure 1 Solution Overview

This trend has been increasing over the past few years and is continuing. Therefore, those who drive to inner Boston face some serious parking problems. Although the main reason behind the parking problem is limited space, this problem is not only caused by the commuters, but is a major problem for any drivers who desire to park in Boston. There are many solutions available to resolve the parking issues in Boston area, but only some of them are viable given the limitation of available budget and time as shown in Figure 1. We will explore various origins of the challenges, and draw possible recommendations.

2.2 Origins of Parking Problems

Boston is a big city with huge amount of traffic flow. Numerous commuters travel the inner Boston daily as shown in Figure 2. Parking problems are expected in consequence of large population injection in Boston (Doyle, 2012). Those who commute to inner Boston usually utilize one of efficient public transportation systems from following three categories: public transportations, automobiles, and biking or walking (Fiske, 2015). If companies provide parking spaces for their employees, large portion of the employees will drive to work because each individual live in different cities. Generally, employees tend to prefer driving to work because having their own cars at work allows them to gain flexibility compared to coming to work without a car.

Figure 2 Boston Traffic (Sheridan,n.d)

2.2.1 Limitations of Public Transportation System

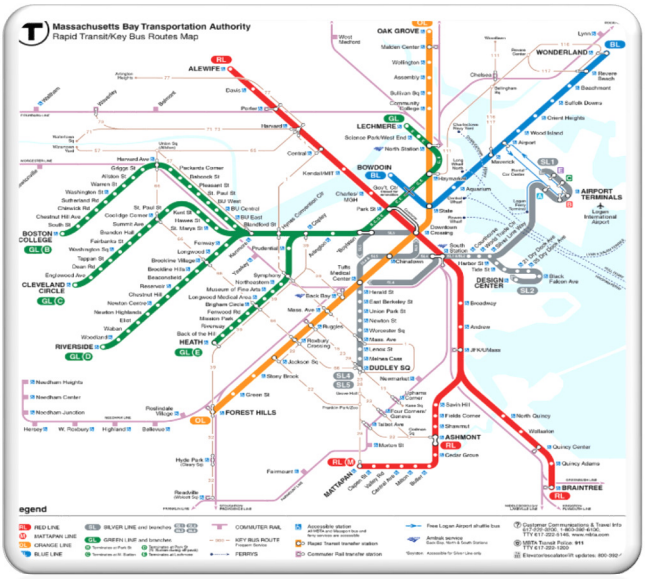


Figure 3 Boston Public Transportation System Map (MBTA, 2014)

Although many companies provide some sort of public transportation services, such as shuttle bus from nearby "T-stations", public transportation system in Boston is still not effective compared to other public transportation systems around the globe as shown in Figure 3. For example, people living in New York can commute to the major areas of the city with the subway system. They can get to work from their home without facing too much difficulty because there are a lot of subways and busses available to the public in order to alleviate traffic problems. Compare to the rush hours in Boston, rush hour in New York is in a totally different scale. Therefore, utilizing public transportation system is usually faster and much more efficient than driving and getting trapped in a rush hour in New York.

Similar situation can be observed in South Korea as well. Seoul is a smaller version of New York. People living in South Korea can get to almost anywhere with public transportation as shown as on Figure 4 (Ro, 2002). Although the public transportation system alleviates some of the traffic problems, public transportation system alone cannot support the growing population. People who utilize the subways and busses to commute still experience the rush hour. Commuters sometimes have to wait for 3 busses or subways to pass in order to find some space to squeeze in as shown in Figure 5 (Ba Tran, 2014).

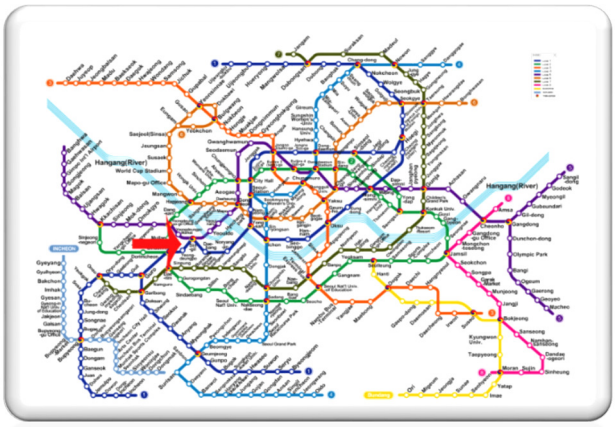


Figure 4 South Korea subway Map (Shaw, 2012)

Figure 5 South Korea subway system during Rush hours (Photobucket, n.d)

However, people living around Boston cannot easily utilize the public transportation system because the public transportation system is very limited to those who live in the rural area. Although commuter rail is an option for rural public transportation commuters, majority of the population still do not have direct access to commuter rails because they are simply too far away (Fiske, 2015). Although there are reasonable numbers of subway stations and bus stations available in the inner city, there are not many subway stations or bus stations around the rural side of the city (Massachusetts Bay Transportation Authority, 2014). Furthermore not many busses operate on the rural

community, and subways systems are not accessible from I-95 areas. For those people, who do not have an option to utilize public transportations, are forced to drive into the city.

2.2.2 Limited Parking Spaces

Boston has extremely limited space for any public parking spaces. Various kinds of regulations on the streets limit the public parking spaces. Some of parking problem factors can be shown in Figure 6. Patrick from Boston Magazine says the following: "*You see, the average car is driven only about 5 percent of each day. The rest of the time—when the owner is at work, at home, or in a store—that car is parked. In a small city with limited space like ours, this creates a major problem,*" (Doyle, 2012). Various regulations on the street such as residential parking spaces, no parking streets, and day only parking streets create many problems. First of all, Boston roadmaps are very old and not effective. Patrick from Boston Magazine states: "*Those of us who live here are well equipped to deliver detailed lectures on the reasons why: one-way streets derived from 17th-century cow paths; the lack, for the most part, of a grid; poor to nonexistent signage; and the general willingness of citizens on foot, on bike, and behind the wheel to dart out recklessly into traffic."* Furthermore, the city previously banned private garage in order to comply with the Clean Air Act. (Doyle, 2012). However, banning garages did not reduce the number of cars, but increased the parking and traffic problems in Boston. Furthermore, the coin meter parking price was only increased by

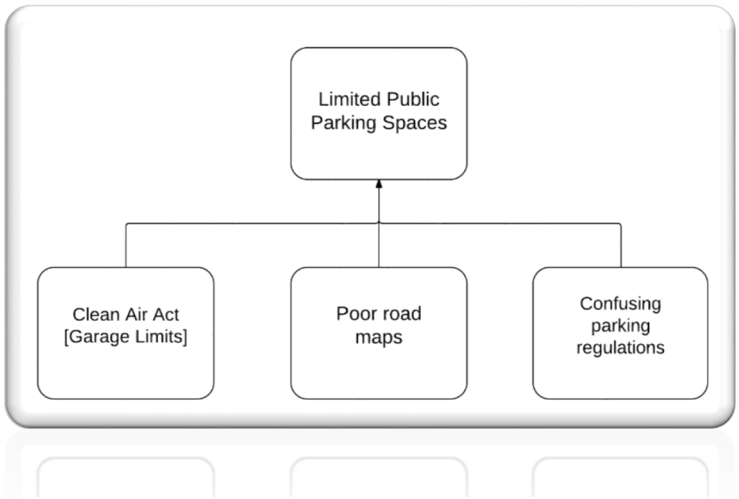


Figure 6 Causes of limited parking spaces

a quarter in the mid-1980s. This is a serious problem we need to address as Boston residents. Parker talks more about this problem: "*Why does all of this matter? Because when you combine low street-parking prices with a cap on the number of garage parking spaces, what you get is a mad dash for street spots and super-pricey garages. Today, according to Colliers International, Boston is home to the second-most-expensive parking garages in America, trailing only Manhattan,*" (Doyle, 2012).

2.2.3 Limitations of Public Information

There are two main issues with the limited public information: limited empty parking space information, and limited public parking space information. Let's discuss limited public parking space information first. Limited public parking space information refers to "*Can I park on this street?*" Basically, the drivers need to pay attention to the signs on the street. Depending on the sign, drivers might be able to safely park on that street for up to 6 hours (Doyle, 2012). However, some streets do not have visible signs located. Furthermore, there aren't any easy ways to access those information online or offline. The simplest way to obtain those information is by experience. Once drivers get some parking tickets and fines, they understand where they should park, and where they should never even attempt. Another big issue is the limited real-time empty parking space information (Doyle, 2012). Public parking space can be emptied at any time of the day because people who park there only park in that location for a temporary time period. The best way to detect or find whether there is an empty space on a public street parking area is by directly looking and searching for it. This method is very inefficient, but it is the most effective way to find an empty parking space in 2015. For example, in Newbury Street, many drivers illegally double park and wait until a space opens

up so that they can park in those empty spaces. This not only hinders the traffic, but also can lead to devastating accidents for the bikers and the people on the sidewalk.

2.3 Importance of Finding Parking Space in Boston

Commuters who commute to inner Boston get less headaches because their employers usually have solutions to the parking problems. Many companies have their own parking spaces, so employees can drive to work, but not many people drive to work simply because there's too much traffic. The companies without the parking spaces usually offer some compensation such as monthly T-pass.

Limited parking spaces lead to limited in-city mobility (Fiske, 2015). Mobility within the inner city of Boston is severely limited by the available public parking spaces. One of the major issues of Boston parking problems is due to limited public parking spaces (Ba Tran, 2014). Boston is one of major cities in United States of America. However, it is a small city with a huge amount of population. Numerous people live and work in Boston. Consequently, a lot of businesses are located in Boston. Different kinds of businesses like clothes shops, malls, restaurants, hotels, IT services and many others thrive and are clustered in small amount of spaces. Despite the limited space, those businesses usually require the customers to physically come to the office for the service customer wants (Walsh, 2015).

Although large percentage of those customers are commuters who can reach the businesses in Boston by either walking or by public transportation, majority of the people are from outside of Boston (Walsh, 2015). Majority of those customers need various kinds of services. Like mentioned above, those services are more likely available in Boston due to greater amount of businesses in Boston. Furthermore, those businesses usually provide more professional services compare to the local shops or stores. Those customers usually drive into the city before or after rush hours to avoid traffic, but they still face the parking problems in the city (Broshanan, n.d).

Parking problems are essential obstacles tourists must overcome. In 2013, "*Average length of stay for domestic visitors was 2.5 nights; Average total spend for leisure visitors was $572 per night; Average party size for leisure visitors was 2.1; approximately 40% of visitors' spend was for accommodations and 60% was for dining, entertainment, shopping and sightseeing,*" (Boston Statistics, 2014). As mentioned before, tourists have some serious difficulties navigating around in Boston. There are lots of one-way streets with confusing signs that hinder tourists from finding the correct places. Furthermore, navigating with public transportation system such as MBTA is not so easy due to confusing system.

2.4 Current Parking System in Boston

2.4.1 Various Types of Public Parking Systems

As mentioned before, the public parking spaces are very limited in the city. For example, parking in Newbury Street in Figure 7 is extremely difficult. However, there are a lot of private parking space available in Boston as well. Private parking spaces are usually moderately maintained, but are very expensive compare to public parking spaces maintained by the government (Conti, 2014). Private parking spaces are more expensive due to the expensive land and maintenance price, but they are usually available for anyone who needs them. Since private parking is expensive, drivers prefer public parking spaces.

Figure 7 Newbury Street (AGIM, n.d)

Figure 8 Coin Based Meter Parking (Silva, 2014)

There are couple different types of public parking available in Boston: coin parking meters, electronic parking meters, hour based street parking, and public lots. Coin parking, as shown in Figure8, accepts 25 cents coins and each coin can add certain amount of parking time. Coin parking also has designated parking space, so drivers must park on a specific space. Coin

parking meters existed since a long time ago, and are still widely used throughout Boston area (Broshanan, n.d).

Electronic parking meters, in Figure 9, are one of the new parking payment systems. Electronic parking meters allow drivers to pay with cash or credit card, so it is much more convenient. However, Electronic parking meters do not have a designated parking space (Conti, 2014). As long as drivers pay for the parking time, they can choose to park anywhere on that street, but with the printed parking receipt visibly displayed on the side window of the car. For example, Newbury Street utilizes electronic parking meters. Newbury Street is always crowded and is difficult to find a parking space in most time of the day. Many great restaurants and various kinds of shops are on Newbury Street, so a lot of people attempt to park on Newbury Street. However, limited parking space does not allow all people to find the parking space around Newbury Street. Usually, there are no empty spaces due to cars filling up the spaces immediately once someone leaves.

Figure 9 Electronic Parking Meters (Thorsen, 2012)

Hour-based street parking also has a long history. Hour-based street parking spaces are completely free, but usually there's a time limit for a parking time (Broshanan, n.d). There are no designated spots for street parking. However, there are not many hour based street parking spaces available in Boston. Hour-based street parking does not produce any revenue, but the city has to maintain the street; therefore the city does not want to have many of them

(Broshanan, n.d). Hour-based street parking is more of a burden for the city whereas it is extremely beneficial for the automobile drivers.

2.4.2 Commuter Population in Boston

Google map provides a typical traffic of a specific day of the week and specific time of the day. Figure 10 on the right shows the typical workday morning traffic. This shows that a lot of people are going towards the "inner-Boston" area and creating a huge traffic congestion problem in highways I-90 (Known as Mass Pike), I-95, and I-93. The exact opposite situation happens around typical weekday around 5pm. Figure 11 shows a typical traffic situation on a typical weekday around 5pm. Commuters start going back to their home located in various suburbs around Boston. This creates a huge traffic congestion in the opposite direction in the same highway systems. There's a huge floating population around Boston area that experience this huge traffic problem. Driving from outside Boston (I-95) area to inside Boston typically takes around 30 minutes, but the traffic congestion can delay this up to 2 hours or more. Commuters from Rhode Island sometimes choose to drive to work after 9am because they would arrive at

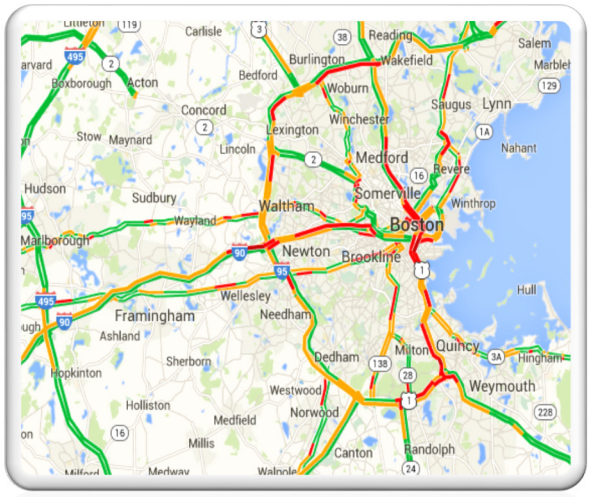


Figure 10 Typical Weekday Morning Traffic (Google, 2015)

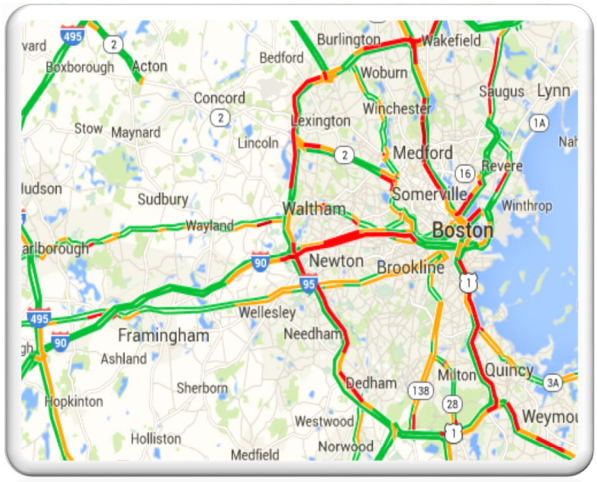


Figure 11 Typical Weekday Afternoon Traffic (Google, 2015)

work around 10am no matter when they leave to work. If they choose to go to work at 8am, the traffic delays them for about two hours, so that driving to work at 9am without the traffic is effectively same for them.

2.5 Previous Solutions to Parking Problems

2.5.1 Rental Bike in Boston

Boston is a small city with numerous small roads. Boston city map does not resemble the chessboard and is not as neat as that of in New York or other cities in the World. Because most of the roads and buildings were planned very long ago, the city plans are not suitable for current population. Excessive amounts of one-way streets and small roads block big truck and van drivers. However, Bicycle can go almost anywhere.

Figure 12 Hubway in Boston

Anyone can go anywhere by bicycles in Boston. There are a lot of ways people utilize bicycle in Boston, especially around college campus. A lot of inner Boston residents are actually students (City of Boston, 2015). Students usually utilize the public transportation system to get to their classes, but bicycle is one of cheap, and effective transportation system for them. There are bicycle lanes in Boston, but the cyclists usually do not have to worry about finding a bicycle lane because they can simply occupy a car lane and bother them (Hubway, 2015).

Because bicycles are effective modes of transportation in Boston, the city created a nice plan called the "Hubway", Figure 12. "Hubway" partially comes from a word "Subway", combined with a "Hub", meaning connecting different places. Hubway is essentially a bike sharing system. Currently there are more than 1,300 bikes in 140 different stations in Boston, Brookline, Cambridge, and Somerville (Hubway, 2015). Those cities are the major cities that

people visit often. If anyone needs to go to a grocery shop that is about 5-miles away, Hubway is a great solution for them. Although the Hubway system is mostly closed in the winter season, it is an effective way to navigate in Boston without any automobiles. Currently Mass Department of Transportation and the Massachusetts government are continuing to expand this service to other nearby cities in order to reduce traffic congestions.

2.5.2 Efforts in improving Public Transportation Systems

Officials and the public transportation department of Boston are trying to make some changes in order to improve the public transportation systems, Figure 13. Current public transportation systems in Boston are not so great. 20 minutes by driving distance can be an hour long by public transportation system because of the transit wait time, (Birbuam, 2013). However, many people utilize and rely on public transportations to get to their schools and work places. Recently the state invested about $200 million into MBTA renovation project. This Fairmount commuter rail line project connects from Hyde Park, Dorchester, Mattapan, and Roxbury to South Station, (Birbuam, 2013) there will be more stations opening with rapid transits. The mayor, Walsh, and Rick Dimino, the president of "A Better City" are planning to help and aid this project. Walsh, especially, wants to improve the bus line as well. He mentioned: "We've also got to look at additional service, bus lines, and more frequent bus lines. And the way I would do that as mayor of Boston is to work with MassDOT and the MBTA, Figure 13, to get that additional

Figure 13 M.B.T.A (MBTA, 2014)

service." Furthermore, he mentioned about the parking problems and wanted to address the frustration, (Birbuam, 2013).

Not only the city officials, but the MBTA is also trying to improve various bus routes. In 2013, the MBTA pointed 15 of the busiest bus routes as the "Key Bus Routes". Each one of those key bus routes operates very frequently, 7 days in a week, in order to meet the passenger demand. The impressive part of the operation is that the service frequency. Sometimes the busses operate every 10 minutes (DeLeuca, 2015). MBTA designed this project in order to improve the overall quality of the service. MBTA wanted to enhance customer comfort, convenience, safety, and, especially, accessibility. MBTA improved the bust stop locations by eliminating or relocating them. MBTA also extended some curbs and implemented queue jump lanes with transit signal priority (MBTA, 2014).

2.5.3 Uber and Taxi in Boston

Taxi used to be another major form of transportation around Boston area, but personal drivers from Uber started to overtake taxi in Boston market. In order to understand the reasons behind decline in taxi market, Uber, in Figure 14, system must be understood first. Uber is an app-based transportation network and taxi company. Uber provides smartphone applications to receive ride requests and distribute those request among the Uber drivers. Uber drivers can be anyone who signed up on Uber application. Depending on the vehicle size and type, different classes are offered to those

Figure 14 Uber and Taxi (Uber, 2014)

drivers. Types range from UberX, Taxi, Black, Suv, and Lux and users can choose which type they prefer for a quick ride (Pilieci, 2014). The invasion of Uber drivers significantly damaged the taxi industry in Boston. Because Uber drivers are much cheaper compare to taxi fare, many people prefer Uber instead of taxi. Furthermore, Uber is more readily available for faster service compare to taxi because Uber drivers are more prevalent than taxi drivers. Despite some advantages, Uber poses some disadvantages for the customers as well. There are no requirements or regulations for Uber drivers; anyone can be an uber driver which is very dangerous (Pilieci, 2014). Furthermore, Uber fares vary depending on different circumstances. If there's a significant demand in Uber drivers in a certain area, the Uber fare sometimes doubles which approximately equals taxi fare. In this way, Uber can monopolize the taxi industry and regulate the fare afterwards (Dungca, 2015). There are couple advantages and disadvantages to Uber and Taxi drivers. It is crucial to understand that both Uber and Taxi need to present and compete each other to meet the reasonable price for the travelers in Boston (Dungca, 2015).

2.5.4 Findings and Discovery from Institutional Research

Finding parking spaces in Boston is important, but collecting the parking space statistics is also equally important. The ParkNet paper, (Mathur, 2013) presents various techniques to collect road-side parking statistics and data. The author also agrees that information is really key factor in finding parking spaces: "*One key factor contributing to excess parking vehicle miles is a lack of information about roadside parking availability. While occupancy data for parking garages is relatively straightforward to obtain through entry/exit counters, data is generally unavailable for road-side parking*." It is easy to determine number of spots in a garage, but road-side parking is really hard to collect data from.

The author presents a "Drive-by Parking Monitoring" technique which the drivers automatically send parking space data by driving around the city. This knowledge can be transferred back to the drivers who are in need to parking spaces because "*Finding street-side parking in a crowded urban area is a problematic task and one that most drivers dread. Finding a parking space near one's destination could be much easier if there were a way to know ahead of time which areas have available parking spaces. Often times, a street only a few blocks away might have vacant parking spaces but a driver looking for parking has no way of knowing this,*" (Mathur, 2013).

Excessive parking space is not a solution to a current parking problems. Just by creating more parking spaces in Boston is definitely not a great solution because the demand for public parking spaces varies by the region of the city and by the time of the day and of the week. A recent study from Northeastern University professor, Stephanie Pollack, revealed some interesting characteristics about the residents in Boston. She studied gentrification around transit stops across the country. She discovered that one of the biggest mistakes municipalities make is requiring too much parking. Her data shows that residents will self-select based off of the situation, meaning those who drive a lot choose to live in a home with parking spaces, but those who do not drive a lot choose transit-oriented homes with no parking spaces. In her conclusion, the answer to urban parking solution is not just creating more parking spaces. She mentioned that parking demand is not monolithic (McMorrow, 2014).

2.5.5 Parking Assistance Mobile Application

There are couple mobile solutions available in order to help drivers to find parking spaces effectively. No one likes to wait to find a parking space. It is a painful process for drivers who want to park and drivers who want to drive through the parkers. In order to eliminate the annoyance of drivers who cruise the public parking meters to park their cars, Boston's Department of Transportation recently released a mobile application that helps the users to find empty parking spaces. Figure 15 shows that mobile solution is one of the solutions that we will focus on.

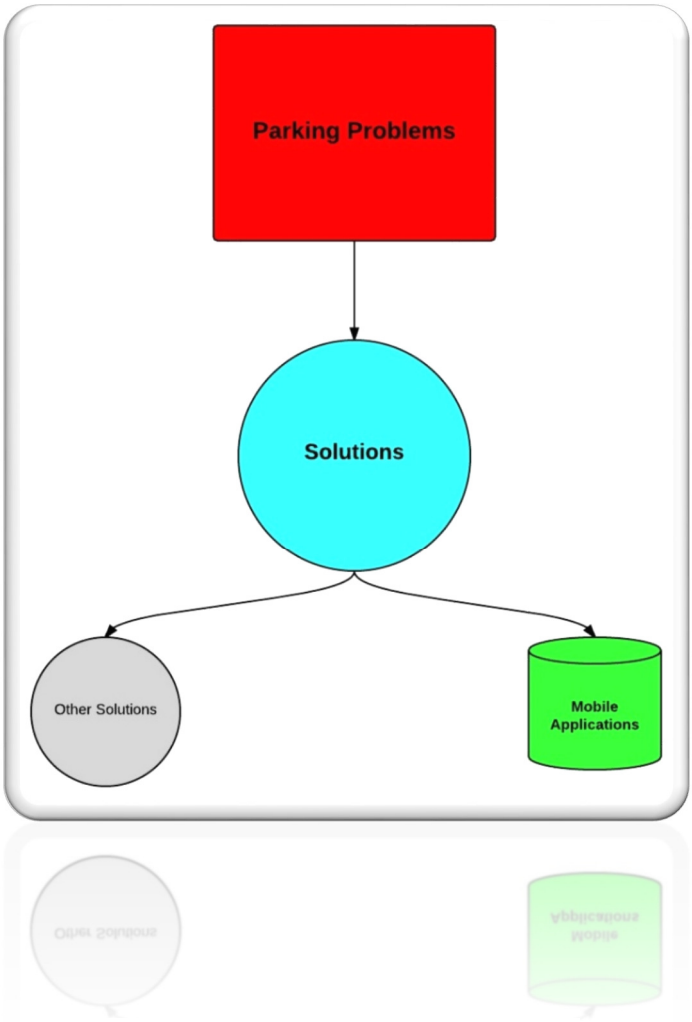


Figure 15 Mobile Solution

Boston recently installed 330 "Smart Parking Sensors" and activated them in the "innovation District" in order to alleviate the traffic congestion and flow in the waterfront areas in Boston. The former Mayor Tom Menino said: "*The installation of this new equipment will now ensure a quicker and more pleasant trip to this neighborhood for those commuters and visitors who choose to drive,*" (Annear, 2013). The parking sensors send continuous signal to the database of Parker smartphone app to alert the empty parking spaces for the drivers to hunt. Those sensors are installed along "*stretches of Seaport Boulevard, Congress Street,*

Summer Street, and Boston Wharf Road as part of a partnership with California-based Streetline, Inc." (Annear, 2013). Although not a great amount of streets are covered with this innovative sensors, Boston city and the government are trying to address the parking issues and problems in Boston.

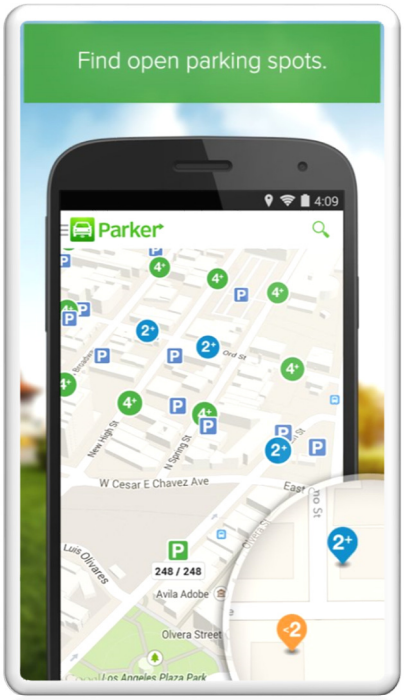


Figure 16 Parker Finding Spot Screen (Streetline Inc, 2014)

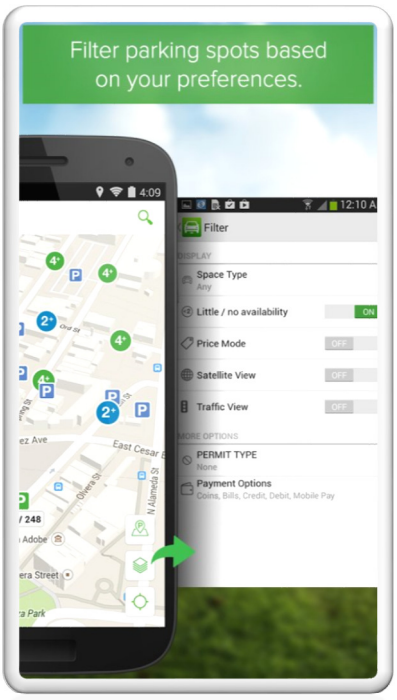


Figure 17 Parker Filtering Search (Streetline Inc, 2014)

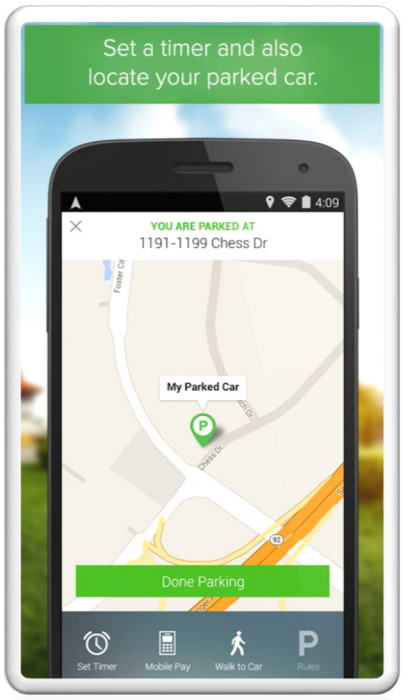


Figure 18 Parker Saving My Car Location (Streetline Inc, 2014)

"Parker" provides notable core features. Figure 16 shows one of the major features and unique feature of the application: searching and finding public parking spaces as well as private parking spaces. This feature is unique because there are no current applications that help users to identify free public parking spaces. Figure 17 shows different set of filters that users can easilly check in order to find certain types of parking spaces such as coin meters or private garages. In figure 18, parker application presents another unique feature of the

application: saving and recognizing my parked car location. This feature also allows the users to set the timer if the parking space has a time limit.

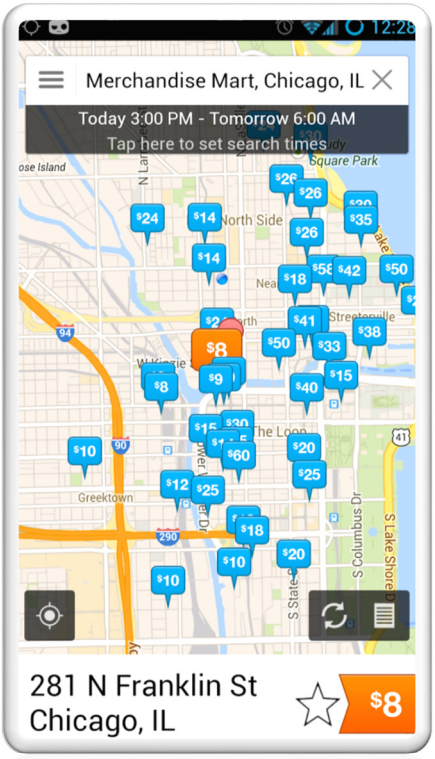


Figure 19 SpotHero Main Screen (SpotHero, 2015)

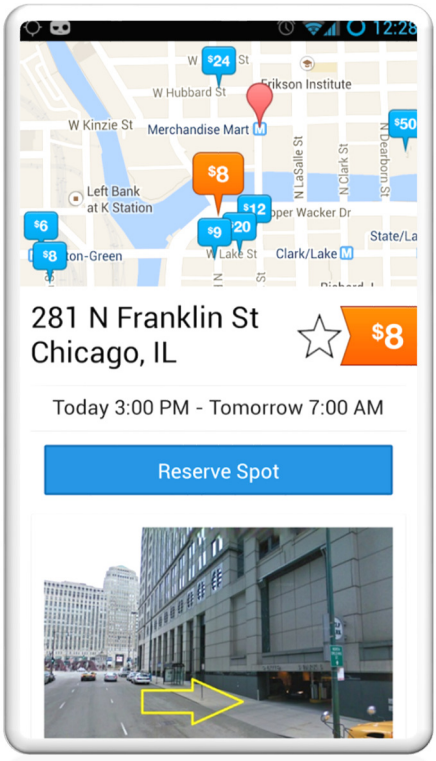


Figure 20 SpotHero Detailed Information (SpotHero, 2015)

"Spot Hero" is another mobile solution and platform available for the vehicle drivers in Boston. A mobile app called "Spot Hero" shows multiple parking garage locations. In Figure 19, SpotHero shows multiple parking garage locations as well as their prices. In Figure 20, detailed information of a selected parking garage is shown. SpotHero shows a great detailed of information to the users effectively by including the time window, contact info as

well as presenting parking reservation system. The prices for those lots are not as cheap compare to the prices for the parking meters, but the prices are cheaper than a normal private parking lots.

Figure 21 Waze Navigation Screen (Waze, 2014)

Figure 22 Waze Current Traffic (Waze, 2014)

"Waze" is a traffic database mobile application. The mobile application takes all of the traffic data from nearby location and informs the drivers the most effective path from one location to another location. As shown in Figure 22, Waze outsources traffic information from the users and re-routes them if the current route is too crowded just like in Figure 21. This mobile solution provides a great service in order to alleviate both traffic congestion problem and the parking space problem (Waze, 2015).

Each one of the mobile applications contains different set of features. However, none of the mobile application has all the features. Table 1 displays the analyzed mobile applications

features. Table 1only show what features are available, but the table do not contain detailed information of the features. Table 2 summarizes the advantages and disadvantages in each application.

Table 1 Mobile Application vs Features

Applications / Features	Waze	SpotHero	Parker
Socialization Features (Profile, Communication)	✓	✓	✗
Map Features (Browse, Navigate, Search)	✓	✓	✓
Real Time Traffic Data (Real time traffic)	✓	✗	✗
Finding Public Parking Spaces (Coin, Meter, Street)	✗	✗	✓
Finding Private Parking Spaces (Garage, Lots)	✗	✓	✓
Showing Detailed Parking Space Info	✗	✓	✓
Providing Filters for Different Parking Spaces (Type, Time)	✗	✓	✓
Providing Location and Time Tracker for User's Car	✗	✗	✓
Providing Mobile Payment or Reservation	✗	✓	✓

Table 2 Mobile Applications Advantages and Disadvantages

Rating / APP	Advantages	Disadvantages
Waze	• **Shows real-time traffic data with high accuracy.** • **Social features allow interaction between different users for greater community**	• **Does not have parking spot searching ability.**
SpotHero	• **Shows great detailed information for the parking spaces such as contact info, price, direction, and websites.** • **Allows reservation on the mobile device.**	• **Does not have public parking spot searching ability.** • **Does not have effective traffic-navigation ability.** • **Social aspect of this application lacks interaction compare to Waze**
Parker	• **Shows combination of private and public parking space information.** • **Provides time and location tracker for user's car.** • **Contains a great filter for finding private, public, coin, street, and accessible parking spaces.**	• **Compare to SpotHero's detailed information, Perker's detailed parking space info lacks detail.** • **Social aspect of this application lacks interaction compare to Waze.** • **Not many public parking space information is included.**

Although there are different features available in different mobile application, none of those applications solve the customers' needs completely. In order to understand the customers and provide various sets of features for them to utilize in a crucial parking situation, we will combine some of the features listed above and redesign some of the features for increased usability.

3. METHODOLOGY

The goal of this project is to propose and produce effective public parking system in Boston for both residents of New England and tourists. The key objectives identified in order to complete the original goals are:

1. ***Surveying the Demands from Potential Users.***
2. ***Understanding and identifying issues from Boston Urban Planning.***
3. ***Analyzing & Designing an innovative Smart Parking System.***

In the following sections, we present how each objective is addressed.

3.1 Surveying the Demands from Potential Users

In order to better understand the community's knowledge regarding the Boston parking problems, accurate data for detailed statistical analysis is crucial. For this process, we collected multiple statistical data from the potential user groups and gathered requirements from them. The collected data contains various kinds of data such as home location, work location, inner-Boston travel frequency and time, gender, age, handicap level, public parking space frequency, private parking space frequency, number of parking violation per-year, and desired features for the mobile application.

We surveyed multiple users from various sources using Qualtrics software. University level students and faculty members were selected including Worcester Polytechnic Institute community members. In order to measure and analyze the data gathered, appropriate questions were included to capture the similarity within certain groups. Questions were designed so that the users can pick from the categories so that it is easier to perform the data analytics on those

dataset. The exact survey that was used to measure the parking problem is shown in Appendix A.

In order to analyze the collected data from the multiple online, specific responses and preferences regarding unique characteristics of parking designation were analyzed. Each surveyors possessed different types of characteristics and parking problems in Boston and thus can categorizing the responses from the users were useful for highlighting important discovery in this survey data.

This survey served as a foundation for the entire project. Gathering requirements for any product is essential. This survey provided some very important aspect of the problem and was especially beneficial when creating a list of requirements and recommendations for different groups to consider. The information and knowledge gained during the survey process served as a strong foundation for the remainder of the project. The surveys not only supplied relevant information pertaining to Boston parking problems, but also offered additional insightful resources for the technical implementation stages of this project. Surveys also provided feedback and suggestions for the overall direction of the parking problems. This invaluable information served as a key component in the development of the Smart Parking Mobile Application.

3.2 Identification of Boston Urban Planning

3.2.1 Addressing Existing Problems in M.B.T.A

Understanding the underlying causes and critical issues in M.B.T.A is significantly important for identifying one of the key objects in this project. M.B.T.A provides three different kinds of public transportation system around New England area: Commuter rails, subway systems, and bus lines. From the data provided by M.B.T.A, there were not enough numbers of busses and trains for the people to use it. Consequently, the wait time for the transportation means to arrive to a given station was longer compare to other major cities with good public transportation systems. Although M.B.T.A provides reasonable services in the rush hours, the service is very limited in the holidays and weekends. M.B.T.A does cover a large portion of the community, but it does not cover all the rural areas in Massachusetts. Furthermore, the M.B.T.A covers the important section of the cities, so the M.B.T.A customers would have to walk to the limited stations in their hometown if available. Furthermore, M.B.T.A transit and service combination greatly increased the travel time because of the long transit time between different service lines, (MBTA, 2014). Resources from online feedback sources such as journals and articles were analyzed. Information collected from MBTA websites such as MBTA coverage map, and transit time tables were combined for the analysis.

3.2.2 Identifying Current Problems in Boston Road Maps

Boston urban road planning has some serious issues. Not only the roads are narrow and confusing to navigate, but also are dangerously planned. Back in the 90s, the road maps were not a big problem. With the recent increase in number of automobiles and traffic congestion, Boston now faces some serious problem. There are lots of one way streets in the downtown area. This confuses many drivers without any sort of navigation system attached to

their cars. On a crowded Newbury Street, every other street is a same direction one way street. This system is very confusing not only for the tourists, but also for Massachusetts residents. Furthermore, there are some section of the streets that are virtually impossible to come back without taking a huge detour. Poor road maps also cause some navigational problems. There are many multi-merge lanes in Boston that are very dangerous. Those lanes are very dangerous mainly because multiple lanes merge into one or two lanes. Furthermore, some traffic lane must cross four consecutive lanes in order to make a very sharp left turn. The current road maps are a great danger for a long-lived Boston residents as well.

4. Analyses and Discovery

4.1 Conceptualization of Smart Parking System

Designing and conceptualization of the entire smart parking system is definitely challenging because of the high level of system complexity. In order to ease the communication between the designer of the system and the interested individuals, a simple diagram in Figure 23 is created.

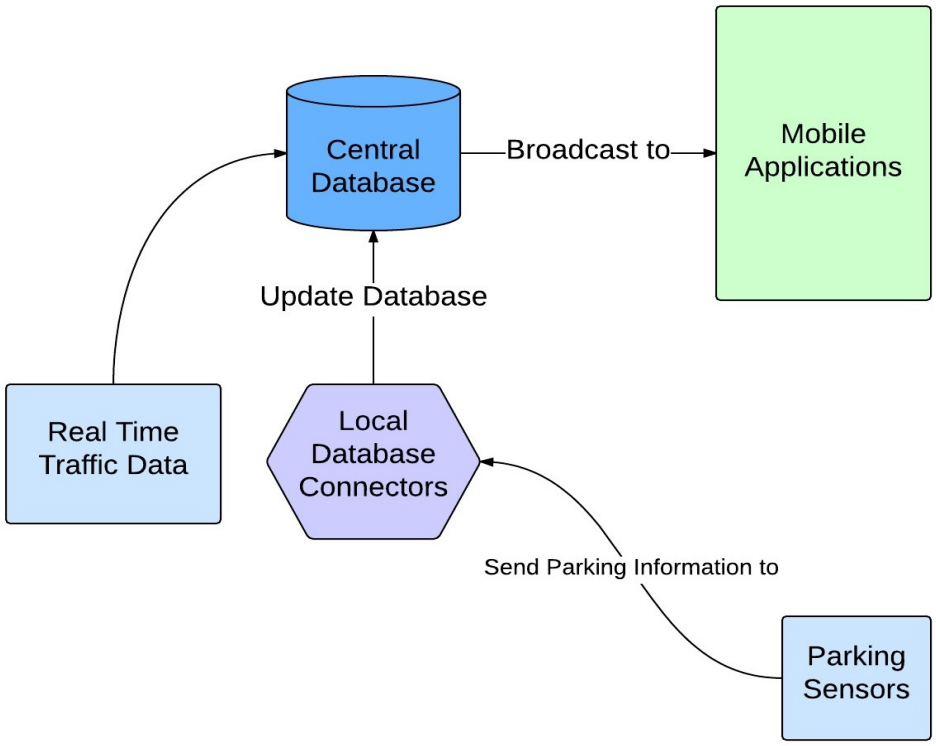


Figure 23 Smart Parking System Simple View

In order to complete all the design requirements of the smart parking system design, the essential three core components are: parking sensors, local database connectors and central database for data collection, and a mobile application for the users to find the parking spaces.

Boston recently installed couple smart parking sensors on their street to collect parking status data in certain side of public street parking spaces. Collecting real-time parking status information in certain locations are extremely important because that information is the important information for the mobile application users.

Parking sensors will detect and determine the status of the parking spot. If there's a car parked in the lot, the sensor will send a request to the local database connectors to update the central database. If there's no car, the parking sensor will still tell the local database connectors to updated the central database, but with "no" instead of "yes".

Central database will maintain all the parking spot information and real time traffic data. The database will have couple of tables for traffic data, public parking space information, private parking space information, parking ban status information, restricted public parking space information, and couple other information. Most parking sensor data will compromise the public parking space information, but most of the private parking data will come from individual vendors or from website scrapers. Traffic data will originate from waze, different types of parking bans data, including winter parking ban status, will get scraped from government's database, and different types of parking types such as residential only parking will also get scraped from government's database.

Once a mobile application user opens up the mobile application, the user's current approximated location will be determined and a request is sent to the central database for nearby traffic and parking information. Once the central database receives the location data from the user, the database sends back nearby parking information with real-time traffic data as well as parking type and ban status data back to the mobile device. Once the user receives

those data, the mobile device renders those data nicely on a map for the user so that the user can find an appropriate parking space.

Table 3 Core Features of EZPark

Features \ Applications	EZPark
Socialization Features (Profile, Communication)	✗
Map Features (Browse, Navigate, Search)	✓
Real Time Traffic Data (Real time traffic)	✓
Finding Public Parking Spaces (Coin, Meter, Street)	✓
Finding Private Parking Spaces (Garage, Lots)	✓
Showing Detailed Parking Space Info	✓
Providing Filters for Different Parking Spaces (Type, Time)	✓
Providing Location and Time Tracker for User's Car	✗
Providing Different Parking Restrictions for Certain Streets	✓
Providing Mobile Payment or Reservation	✗

With the features analyzed from different mobile applications, including Waze, Parker, and SpotHero, new smart parking system mobile application "EZPark" is created. The EZPark mobile application implements core features from each mobile application, but mobile reservation or payment feature was not included. Instead, providing different types of restriction on parking space feature was included. The table 3 below summarizes the core features of the EZPark mobile application.

4.2 Results and Findings from the Survey

Electronically surveying WPI faculty and students definitely provided great insight for this project. The university population was electronically surveyed for approximately for 2 days long starting on the February 20th 2015. There were 122 participants in this voluntary survey. Some of the participants did not choose to answer all of the questions.

Basic Distribution

Among 122 participants, about 51% were male and 49% were female (Figure 24) Although there are more male student population in Worcester Polytechnic Institute, the female population in the faculty balanced and produced a nice even distribution of the gender.

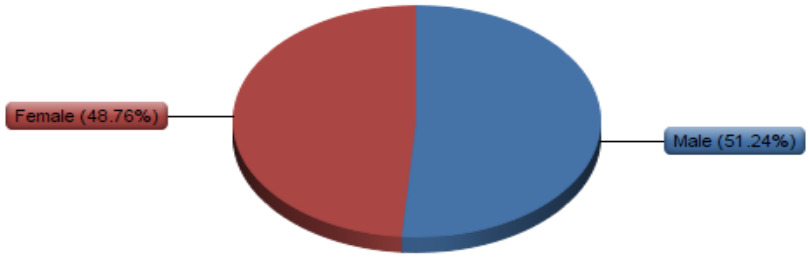


Figure 24 Gender Distribution

Table 4 Gender Distribution

#	What is your gender?	Gender Distribution	Response	%
1	Male		62	51%
2	Female		59	49%
	Total		121	100%

The age distribution ranged from 18 to 80 years old because most of Worcester Polytechnic Institute students are ages of early 20s. Despite major student population, a nice even distribution of age can be observed in the faculty population as shown in Figure 25.

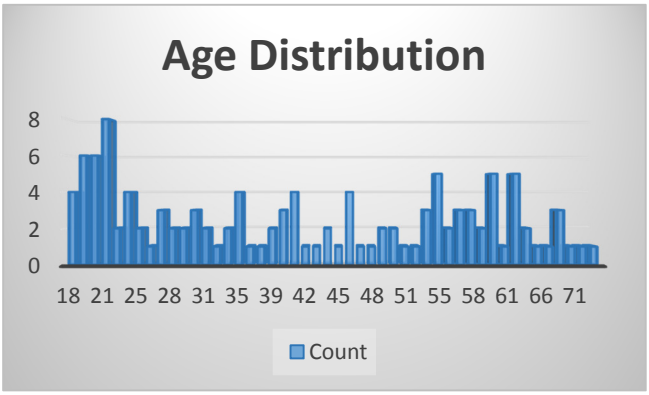


Figure 25 Survey Age Distribution

Although the professors represent groups of age of 40s and 50s, we could observe a nice even distribution of population.

About 70% of the surveyed population lived in either suburb or rural area as shown in Table 5. Interestingly, 27% of the population lived in downtown Worcester. We wanted to capture the traffic difficulty from those who live outside of the downtown area, so we successfully captured majority of those population.

Table 5 Home Location Distribution

#	Home Location	Home Location Distribution	Response	%
1	Downtown Boston		2	2%
2	Downtown Springfield		0	0%
3	Downtown Worcester		33	27%
4	Other Downtown area		2	2%
5	Suburb area		66	54%
6	Rural area		19	16%
	Total		122	100%

For the work location, majority of the respondent answered downtown Worcester as their work location. About 15% of the population answered that they work in suburb area. Because there are more jobs and workspaces available in the downtown area, people tend to get jobs in the downtown area. Total of 84% of the responses represent general downtown area. This shows a lot of population is traveling to downtown as shown in Table 6.

Table 6 Work Location Distribution

#	Work Location	Work Location Distribution	Response	%
1	Downtown Boston		1	1%
2	Downtown Springfield		0	0%
3	Downtown Worcester		94	77%
4	Other Downtown area		7	6%
5	Suburb area		18	15%
6	Rural area		2	2%
	Total		122	100%

About 84% of the population reported that they use some sort of private as a mean of transportation for their work. This is a huge portion of the population. In order to commute from the suburb or rural area, personal vehicle is required. About only 2% indicated that they utilize public transportation system. If this survey was sent to people in downtown Boston, it is likely that more people would have indicated that they utilize public transportation because it is more readily available than in Worcester. 14% of the population indicated that they utilize

neither public transportation nor private vehicle. It is likely that those population represent on campus students who walk or bike to the school as shown in Table 7.

Table 7 Commute Option Distribution

#	Commute Options	Commute Option Distribution	Response	%
1	By Public transportation system		3	2%
2	By Cars(including carpool)		102	84%
3	Others		17	14%
	Total		122	100%

About 61% of the population indicated that they drive to the downtown area at least 5 times in a month. 39% of the population indicated that they only drive up to 5 times into the downtown area in a month. 47% of the population indicated that they drive more than 15 times to downtown area in a month. We wanted to capture the working class and non-working class for our dataset. Those who drive to downtown area more than 15 times a month probably represent the working class. Those who do not drive as much probably represent student or other groups of population as shown in Table 8.

Table 8 Downtown Travel Frequency

#	Travel Time in a Month	Downtown Travel Frequency	Response	%
1	0 to 5		48	39%
2	5 to 10		11	9%
3	10 to 15		6	5%
4	15 or many		57	47%
	Total		122	100%

33% of the survey population responded that they utilize public parking spaces. It is likely that those population do not commute as a work, but commute as a student because public parking spaces are usually unreliable during parking bans and busy rush hours. 55% of the population indicated that they utilize private parking garages or lots. It is likely that those

population represent working class who desire reliable parking spots and can afford the private parking spaces. 12% of the population indicated that they do not drive to downtown. It might be wise to simply not drive to downtown area to avoid any traffic problems. Consequently, average value of parking difficulty level in a downtown area, on a scale 1 to 5, was 2.75. The average level indicates that parking problem does exist, but not to the extreme level. Interestingly, 99% of the population indicated that they get less than 5 parking violation per year. This showed that many people do understand and follow state, city, and government regulations as shown in Table 9.

Table 9 Parking Types Distribution

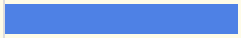
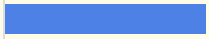
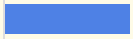
#	Parking Types	Parking Type Distribution	Response	%
1	Street parking(meters, coin, free parking)		40	33%
2	Private parking garage or lots		67	55%
3	I do not drive to downtown		15	12%
	Total		122	100%

Utilizing Smart Data

96% of the population responded that they do not utilize smartphone apps to find parking spots. This response seriously shows that people do not know how to utilize smartphone application to find something they need in their everyday situation. We asked them what features they would like on their smartphone mobile application to find a parking space. The top 5 features the users most wanted were (Table 10):

1. **Finding Public Parking Spaces(Coin, Meter, Street)**
2. **Map features(Browse, Navigate, Search)**
3. **Real Time Traffic Data(Real time traffic)**
4. **Finding Private Parking Spaces(Garage, Lots)**
5. **Showing Detailed Parking Space Info**

Table 10 Desired Smartphone Feature Distribution

#	Desired Mobile Application Features	Feature Distribution	Response	%
1	Finding Public Parking Spaces(Coin, Meter, Street)		91	74.59%
2	Map features(Browse, Navigate, Search)		84	68.85%
3	Real Time Traffic Data(Real time traffic)		79	64.75%
4	Finding Private Parking Spaces(Garage, Lots)		76	62.30%
5	Showing Detailed Parking Space Info		58	47.54%
6	Providing Mobile Payment or Reservation		51	41.80%
7	Providing Filters for Different Parking Spaces (Type, Time)		49	40.16%
8	Providing Location and Time Tracker for User's Car		32	26.23%
9	Social interaction features with other users		17	13.93%

The least favorable feature was the social interaction features. The respondents wants the mobile application for their convenience, but not for the social interaction device. The second most unwanted feature was the location and time tracker. Because location and time tracking can be done by individuals without any assistance, not many people desired the feature.

About 73% of the respondents responded that they would use a mobile app if all the features they selected are implemented. This is a positive response from the respondents. The people did not know the mobile application existed, but they desired a lot of those features.

4.3 U.I Design of EZPark Application

After surveying Worcester Polytechnic Institute professors and students, we could narrow down initial core features for the EZPark mobile application. Understanding the demands and behaviors from the users are critical in user interface design. From the survey, we were able to understand and narrow down the top 5 most desired features of the EZPark mobile application. Therefore, we decided to remove some of the features for later releases and build the mobile application with the core desired features for the initial release.

Main Screen

The survey provided us some great insight. The population did not really want socialization feature of mobile application. However, socialization and personalization of mobile applications are essential key component that makes mobile application successful. Social applications that collaborate and communicate tends to create a great community. Waze is a good mobile application that serves people by sharing their data as a community. We definitely wanted to keep the social aspect, but, only for upcoming features. The main screen has a map component and four different main filters for displaying different parking types. The top search bar and the bottom menu panel does not disappear and stays on for the user all the time as shown in Figure 26.

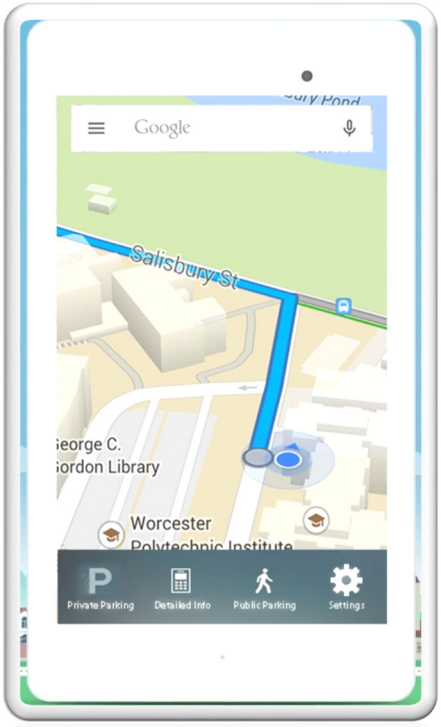


Figure 26 Main Screen

Public Parking Filter

Many users need locate some public parking space information. The mobile application communicates with the central database and updates the map based with data provided by Public Street parking, coin meter and electronic meter locations just like shown in Figure 27. Each side of the street could be a public parking space, but sometimes only one side of the street can be public parking space. In order for the users to easily understand which side of the street is allowed for public parking space, we designed the user interface to have one green line on each side of the street if the street is allowed and reserved for public parking spaces. Once user taps the public parking filter on the bottom menu panel, those green lines will appear on the map. If a user desires to disable them and search for a private parking spaces or turn other filters on, the user can simple tap the same filter to turn it off and turn other features on by tapping them.

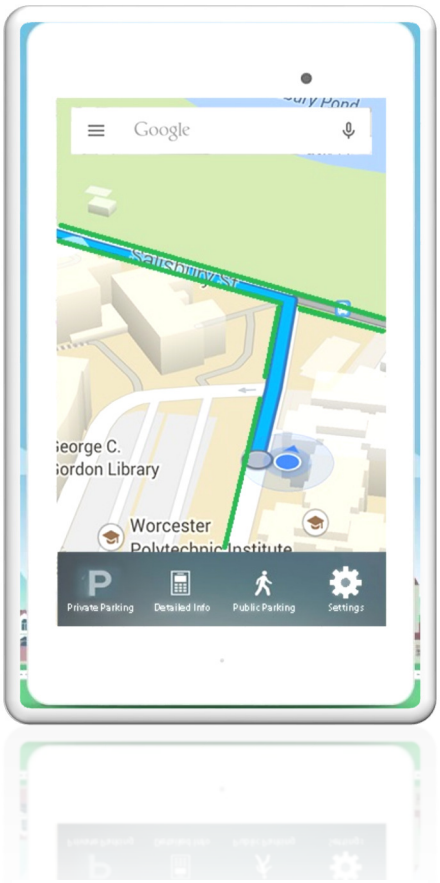


Figure 27 Public Parking Filter

Private Parking Filter

Sometimes public parking is not an option in a big or large city because public parking spaces are rare or some users want to park their cars in more private locations. Private parking filters solve this problem. Users can tap the private parking filter on the menu panel on the bottom to enable the private parking filter feature. Once the filter is enabled, the mobile device communicates with the central database and requests information for nearby private garages and lots. Once the mobile application receives the data from the database, it updates the mobile application by rendering different prices of the private garages and lots. Users can choose to navigate to a private lot or a garage location as shown in Figure 28. Although reservation features are desired for those private lots, it is important to implement the core set of features first, and implement side features in the later stages of the mobile application. Therefore, there are no mobile reservation features yet, but it is definitely one of the upcoming features.

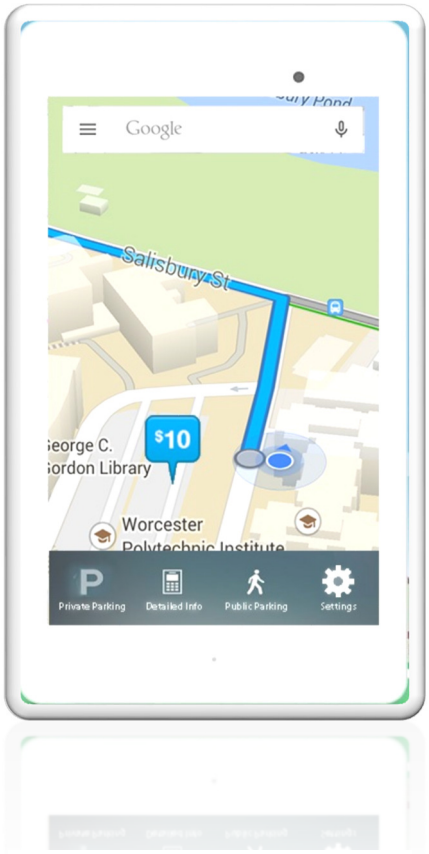


Figure 28 Private Parking Filter

Detailed Info

Downtown parking restrictions change by the time of the day and weather condition. Downtown Boston has "timed residential parking spaces". Those spaces are reserved for Boston residents on certain time of the day. Some streets are resident parking only. Some streets have no signs of parking availability. Snow parking bans are not announced properly. Unless the users lived in the downtown area for more than 5 years, it is extremely difficult to find out a certain street for public parking. In order to assist users who do not understand confusing rules in the downtown area, we have created detailed info filter for them to understand various restrictions for parking in downtown area.

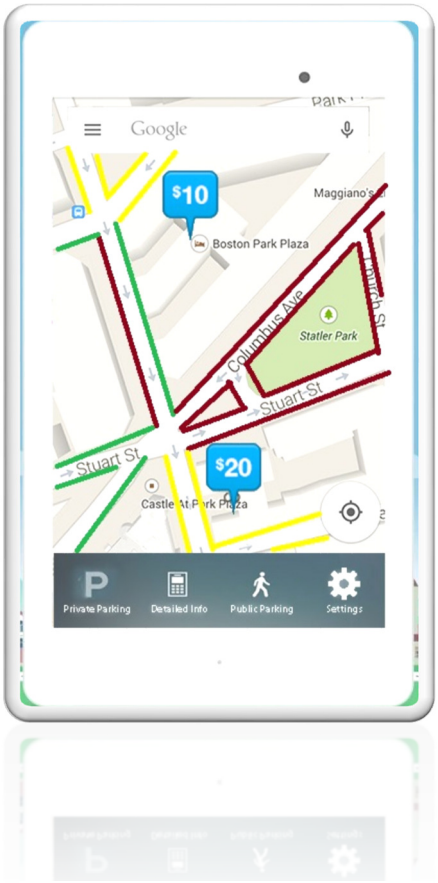


Figure 29 All Filters On

Streets with yellow lines mean those streets could be public parking spaces. Streets with timed residential parking could be an example, meaning drivers could park on those streets until 6:00pm. Once the time passes, the street will automatically turn red. Streets with red lines indicate those streets are not available for public parking. Residential parking, no parking and snow parking ban are examples. Although residential parking allows public parking on Sundays and other holidays, those parking spaces are generally not available for public parking. Snow parking bans are declared, but not well announced for travelers. Providing those information would be extremely valuable for the users as shown in Figure 29.

Settings

Other features are upcoming features for future releases. The initial mobile application will not have many options such as turning on traffic status and finding a parking space in specific time frame, but those features are definitely desirable in near future. Therefore, settings page is extremely important. Once there are more than three filters and more features available, settings page will contain set of those filters and features as a group control format.

5. Recommendations

Based on the findings and analysis of the survey, we created some recommendations that could potentially improve the survey structure and data collections methods for future surveys. Furthermore, multiple great feedback from the surveyed population at the university was included for future suggestions which could improve the future survey methods and design.

5.1 Recommendations for Surveys and Data

The recommendations proposed in this section are based on the survey and data collection techniques presented during the project. In the near future, survey or interview questions could re-phrased more concisely and clearly in order to avoid possible misunderstanding and confusion from participants. Furthermore, some of the options were not available in multiple-choice question. For example a question asking whether a person would utilize smartphone application for navigating and finding parking space had only yes or no for possible answers. Some of the respondents wanted maybe as an option. Allowing these changes will reduce the burden on interviewers and surveyors while increasing the response rate. In the future, we could potentially design couple interview sessions for one on one face interview, so that we could easily capture the details of their responses and analyze them. Furthermore, mail-in survey could be utilized instead of electronic surveys. Although the data processing is more difficult for mail-in surveys, the method allows larger group of population including those who do not utilize electronic devices.

Usage of Worcester Polytechnic Institute Qualtrics online survey tool was helpful, but there were some challenges presented in the software. We wanted to categorize the survey result to find patterns or general consensus. For example, we wanted to find out whether there were some pattern in some age group that experience heavy parking problems. In order to perform these kinds of analysis, deep drilldown techniques are required. Although Worcester Polytechnic Institute Qualtrics does offer some of the drilldown features, the features were extremely minimal. We wanted to drilldown based off of multiple questions such as residential location and work location, but the drilldown feature was only available for one question. Furthermore, Qualtrics does not aggregate user integer input into categories, so we had to use excel for separate age group analysis. Qualtrics also had poor chart rendering systems. Labels on the pie-charts were cut off and not visible for the users, so we could not utilize pie charts on the analysis. Qualtrics can improve its software based on the feedback we produced.

5.2 Recommendations for Smart Parking System

We strongly recommend to produce a functioning prototype with the core set of features for various user testing. The analysis and survey results indicate that more than half of the surveyed population is willing to use the mobile application. Although not all the mobile application features were desirable, the core set of features was moderately enticing and desirable for the users because more than 50% of the population desired those core set of features. Despite these statistical findings, we strongly recommend that socialization feature is extremely necessary for increasing user return rate. Because mobile applications that have socialization features generally have higher return rate. The mobile application exist to broadcast relevant information to the users, but, the interaction and communication feature keeps them coming back to check other relevant information for the users. Therefore socialization feature is extremely important despite the fact that feature was least desired.

We also strongly recommend designing smart parking sensors. Currently there are smart parking sensors available in the downtown area, but designing a different version of smart parking sensors is definitely an option. Because those parking sensors do not record various data, but only the information about vehicle presence, new parking sensors can capture various data such as parking time, parking date, parking weather condition and so on. Those captured data can be uploaded into the central database to create a pattern of parking heat map in order to better understand the current parking patterns.

We recommend the city of Boston to update parking bans through mobile applications. Although the survey results suggest that not many people receive parking violation, understanding parking ban could be extremely difficult for remote people. Because the city

updates parking bans without the details of the parking ban, many motor vehicle operators get confused and have to behave intuitively. Therefore displaying those flash parking bans on a mobile device and announcing them through broadcast from the central database can be extremely helpful.

6. Conclusion

The survey conducted in this project helped to confirm the demands for parking navigation tools and relieve the suspicions of possible misunderstanding of the mobile application features. Because downtown Boston is a very small region of Massachusetts, understanding details of the current parking spaces and problems and analyzing possible viable solutions are vital. In an age when community and societies are filled with motor vehicles, understanding the core heart of the problem is the fastest and most effective way to solve the parking problem. The questions and methods involved in the survey have been modified and refined so that appropriate responses can be gathered and collected from a broad demographic and population group. Recommendations were created in order to aid and improve the survey quality for future research and studies to be conducted in both university and government institutions. Other various recommendations were also generated for improving both survey and data collection methods. Providing a navigation route for parking spaces by incorporating real-time traffic data must be effective. Various parking locations must be identified with different types such as public or private parking spaces. Presenting relevant and useful parking information is extremely important for drivers in downtown area. Similar smart parking system can be utilized in various section of the world including cities in other nations. The surveyed population was very small, so the same survey can be electronically sent out to multiple universities or offices in downtown area to gather more data. A larger survey can be conducted to assess a greater demographic over a broader area. Similar researches or study can be performed and examined in the future in other traffic heavy locations where little of parking problem is understood in order to prepare for the future transportation system or plan to change the current issues or problems in that area. Once the parking problems of a certain

area is identified and understood, the government or a third party can start to develop smart parking system to address the parking problems. Developing effective parking system is extremely important in conserving valuable spaces in downtown area. As stated previously, a significant portion of the downtown areas in the World experience parking problems and traffic problems. Without proper solutions to the parking problems in those areas, individuals will not be able to effectively utilize the limited spaces in those areas, potentially leading to severe discomfort and frustration. Although the parking problems in downtown areas are difficult to address and understand, the efforts from public transportation system, and the government has been improving overtime as more population raises concerns. As study and research are conducted on parking problems, various possible solutions can properly evolve to maximize and utilize the limited parking spaces in downtown areas.

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Appendix A: PARKING PROBLEM ANALYSIS SURVEY

Purpose. **This survey was created in order to understand and measure current parking problems in downtown area. We aim to understand the current parking problems and propose an effective public parking system in Boston for both residents of New England and tourists.**

The survey will take approximately about 3 ~ 5 minutes to complete.

Q1. What is your gender?

- ○ Male
- ○ Female

Q2. What is your age?

Q3. Where do you live?

- ○ Downtown Boston
- ○ Downtown Springfield
- ○ Downtown Worcester
- ○ Other Downtown area
- ○ Suburb area
- ○ Rural area

Q4. Where do you work?

- ○ Downtown Boston
- ○ Downtown Springfield
- ○ Downtown Worcester
- ○ Other Downtown area
- ○ Suburb area
- ○ Rural area

Q5. How do you commute?

- ○ By Public transportation system
- ○ By Cars(including carpool)
- ○ Others

Q6.
How many times do you drive into downtown in a month?

- ○ 0 to 5

- 5 to 10
- 10 to 15
- 15 or many

Q7.
If you drive into downtown, where do you usually park?

- Street parking(meters, coin, free parking)
- Private parking garage or lots
- I do not drive to downtown

Q8.
On a scale from 1 to 5, how difficult is for you to park in downtown?

Difficulty Level

Q11.
How many parking violation tickets do you get per year?

- 0 to 5
- 5 to 10
- 10 to 15
- 15 or many

Q12.
Do you use smartphone apps to find parking spots?

- Yes
- No

Q13. What features would you like on your smartphone all to help you find parking spots? Check all that apply.

- [ ] Social interaction features with other users
- [ ] Map features(Browse, Navigate, Search)
- [ ] Real Time Traffic Data(Real time traffic)
- [ ] Finding Public Parking Spaces(Coin, Meter, Street)
- [ ] Finding Private Parking Spaces(Garage, Lots)
- [ ] Showing Detailed Parking Space Info
- [ ] Providing Filters for Different Parking Spaces (Type, Time)
- [ ] Providing Location and Time Tracker for User's Car
- [ ] Providing Mobile Payment or Reservation

Q14.
If above features are available in an mobile app would you use it?

- Yes
- No

Q15. What features would you like on your smart-phone all to help you find parking spots? Check all that apply.

Submit